VISUALIZATION TOOLS FOR ENERGY AWARENESS AND MANAGEMENT IN ENERGY POSITIVE NEIGHBORHOODS[1]

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ABSTRACT: *In an Energy Positive Neighborhood (EPN) the annual energy demand is lower than annual energy supply from local renewable energy sources. Short-term imbalances in energy supply and demand are corrected with national energy supplies. In this paper, some tools for intelligent management of energy positive neighborhoods are presented. These tools include an energy management tool for real-time management of the energy flows, user interfaces that support energy efficient behavior of the users in the neighborhood and an urban planning decision support tool. These tools have been developed as part of a European co-operation, and are designed so that they can easily be adopted in different European countries with minimum changes. The focus of this paper is the description of the developed user interfaces for energy awareness and management in an energy positive neighborhood.*

KEYWORDS: *Energy positive neighborhood, energy management, visualization, user interfaces*

❖ INTRODUCTION

The EU FP 7 Project "Intelligent Neighborhood Energy Allocation & Supervision" (IDEAS) aims to demonstrate how energy positive neighborhoods (EPN) can be cost effectively and incrementally implemented by designing, testing and validating various software tools and user interfaces. The primary intended user of the tools developed in the IDEAS project is a new type of actor, the energy positive neighborhood service provider (EPNSP, described in Crosbie et al 2014). Currently this actor does not exist as such, but is represented in the project by an energy company at a Finnish residential demonstration site and a facility manager at a university campus in Bordeaux, both of which could be the central actor in the business model. In the business model, some key activities are supported by the control and optimization tools and user interfaces, as well as the decision support tool for urban planning:

1. A neighborhood energy management tool to optimize energy production and consumption;
2. User interfaces that engage communities and individuals in the operation of energy positive neighborhoods;
3. A decision support urban planning tool to optimize the planning of neighborhood energy infrastructures;
4. Business models to underpin energy positive neighborhoods that engage end users, public authorities and utility companies.

The focus of this paper is to report the prototype user interfaces which have been developed as part of the IDEAS project. These user interfaces are a set of software tools. The user interfaces provide intuitive environments that engage casual users and in doing so improve their energy literacy and energy consuming behaviors. The access to the management system data will be provided using web technologies to enable both facilities managers and residents to take advantage of the information presented on the provided interfaces. These user interfaces have been developed based on the specifications originally presented in (Shvadron 2013). These user interfaces will be used at two neighborhood pilot sites within the context of the IDEAS project. These include the University campus in Bordeaux, France and a newly built residential area in Porvoo, Finland. The user interfaces developed cover all the aspects of how users in both IDEAS pilot sites can act and what they will experience as a result of those actions.

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USER INTERFACES FOR ENERGY AWARENESS AND MANAGEMENT

Following user interfaces for energy awareness and management have been developed so far:

1. A shared 3D virtual space, which allows visitors to see and interact in-context with people and visual information related to the energy usage and production in the pilot site in France.
2. A home energy management system which is composed of: (1) an application which displays energy related information on the home TV and (2) a handheld augmented reality application. The goal of both is to help home residents to act upon energy conservation requests and intuitively make decisions on how to optimally achieve their energy demand goals. These applications will be tested over a 9 month demonstration period and results will be obtained to show their effectiveness.
3. An "energy awareness" user interface, which will be installed on wide screens in public spaces within the French pilot site and the Finnish pilot site.
4. Energy awareness tools dedicated to a site Energy Manager (the EPNSP) that were developed in order to better understand how a site consumes and produce energy, and to visualize the output of the energy optimization process."

USER INTERFACES SYSTEM LAYOUT

In order to realize the above functionality, an IT infrastructure has been designed (see Figure 1). This infrastructure consists of a central Smarter Cities and Energy Management System (EMS) (Short et al 2013) which handles and manages all the energy related information for the energy positive neighborhood. Lower level details of the IT infrastructure are given in (Short 2014a and Dawood 2014b). A web interface allows the various user interfaces that serve each pilot site to access the data and interact with it for the above purposes. As can be seen in Figure 1, the IDEAS IT system is designed so that one piece of software can cater for both case study sites. This flexibility demonstrates the potential of the results of the project to be applied in differing areas, thus increasing its ultimate exploitation potential. The EMS is designed to be capable of providing energy management services to several types of EPNs such as those in the IDEAS project – a neighborhood and a large institute. An Urban planning tool (Ala-Juusela et al 2014) provides the ability to design EPNs and provide long term insight of its potential. The IT layout for the local EPN in Porvoo is illustrated in Figure 2.

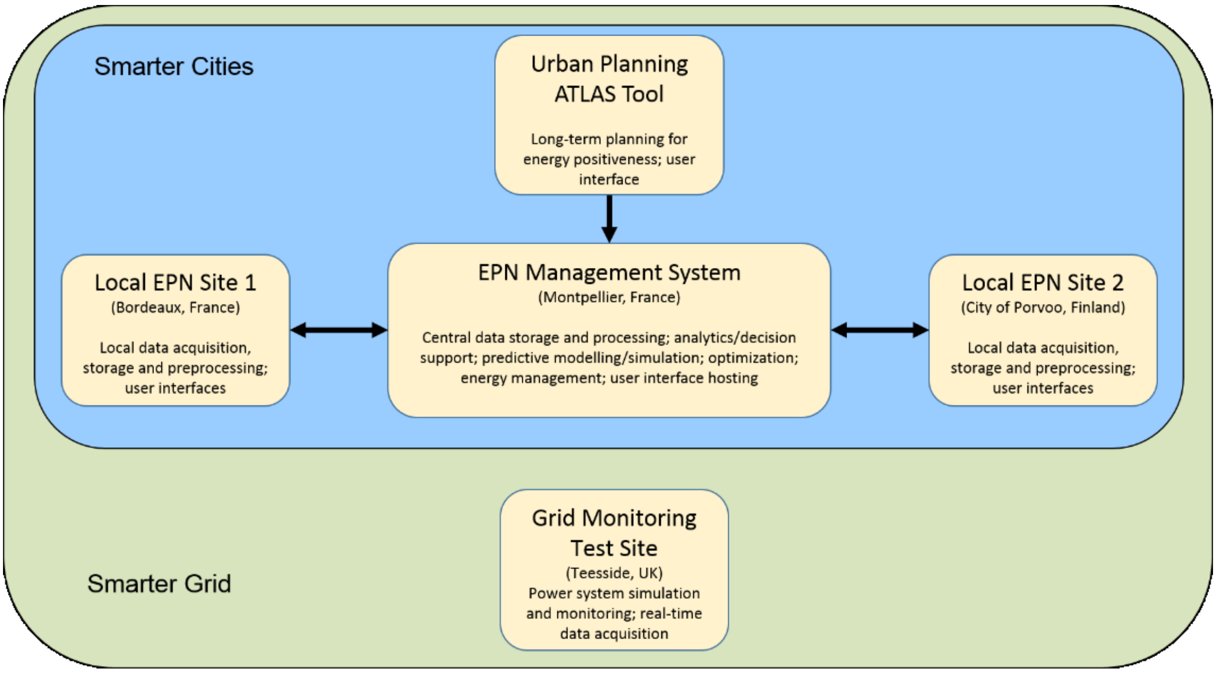

Fig. 1: High-level overview of demonstration sites, IT tools and functionalities in the IDEAS project

The user interfaces in Porvoo are marked in red in Figure 2. These interfaces are:

- Large interactive screens located in the Omenatarha nursery and in the city of Porvoo municipality building. These screen provide EPN related information to the residents of Porvoo
- Home applications that provide the resident detailed information about the energy consumption at home. This information is displayed on the home TV using an application that runs on a small Android device (MK908). Another application which runs on an Android tablet provides real-time information

on the energy consumption of specific home appliances using augmented reality. The energy information is provided by sensors that are connected to the devices.

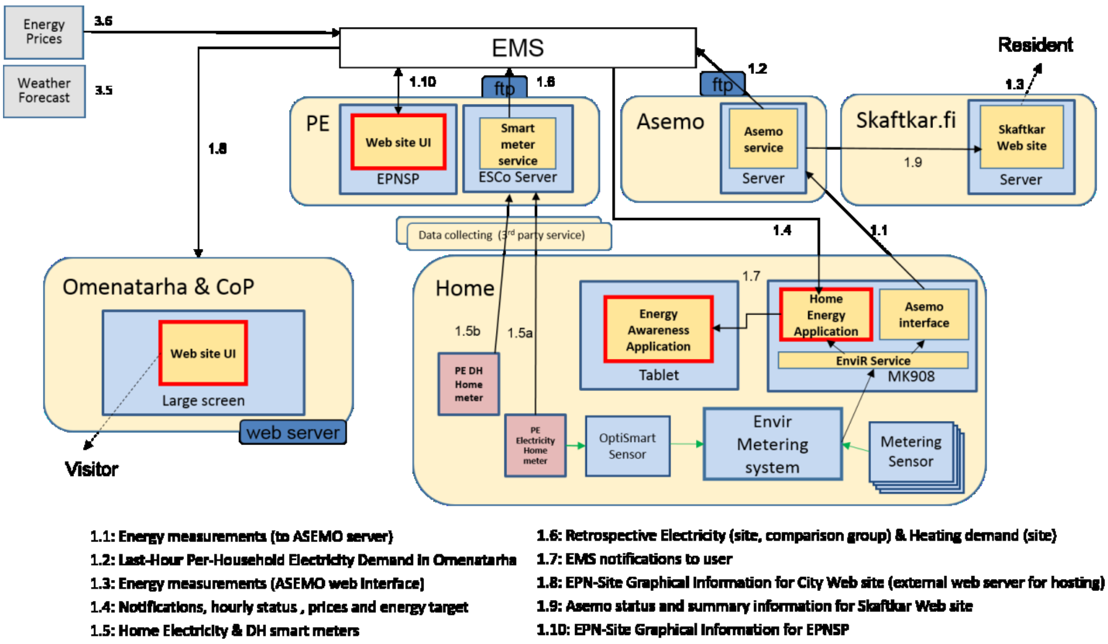

Fig. 2: IT system in Porvoo

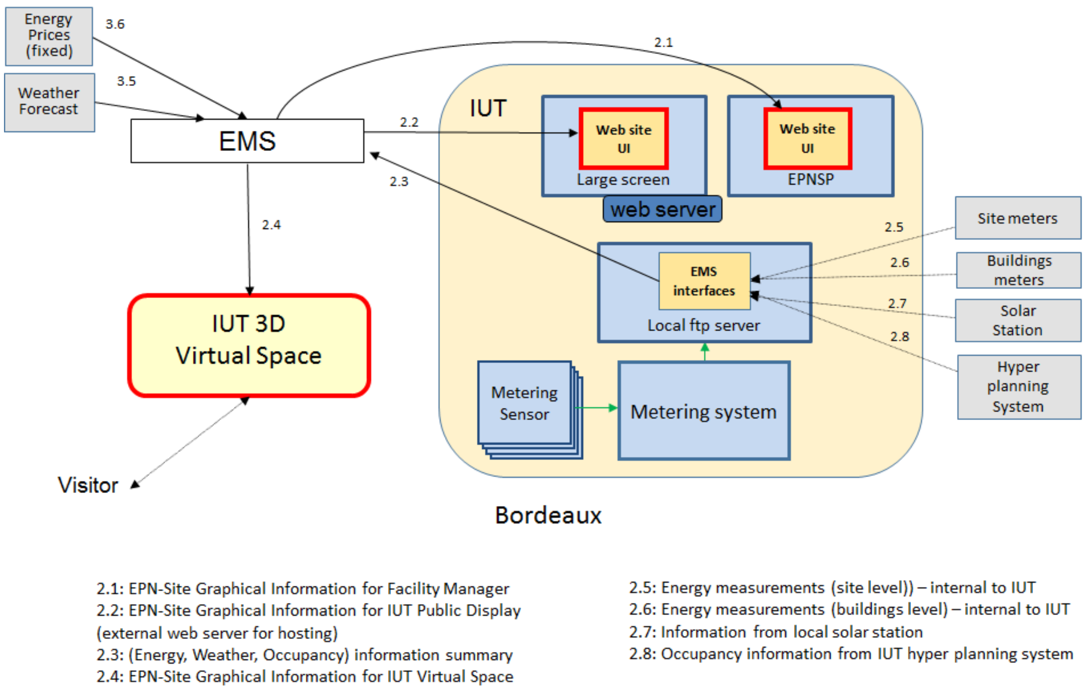

Fig. 3: IT system in Bordeaux

- EPNSP web site provides energy related professional information that enables managing the EPN

The IT layout for the local EPN in Bordeaux is illustrated in Figure 3. The user interfaces in Bordeaux are marked in red. These interfaces are:

- Large screens located in several key places in the IUT buildings. These screen provide EPN related information to the local students, local employees and visitors
- EPNSP web site provides professional energy related information that enables managing the EPN
- A 3D virtual space that enables external visitors to learn about the EPN in IUT. This interface emulates the actual IUT facility with respect to various energy consumption and production aspects.

DEVELOPED INTERFACES

Augmented reality based home Interfaces

This interface was developed in order to realize one of the main goals of the IDEAS project, namely to inform home residents about fine grain energy consumption and to help them meet the energy supply objectives of the Energy-Positive Neighborhood (EPN). During the IDEAS project pilot period the residents of a Finnish neighborhood in Porvoo will be notified by a neighborhood Energy Management System (EMS) about potential actions that could be taken to reduce peak energy demand and shift energy demand to periods when renewable energy is available.

For this purpose two applications have been developed, the Home Energy Application (HEA) and the hand held Energy Awareness Application (EAA).

The HEA application provides the resident detailed information regarding the energy consumption of their home as well as information about the current overall status of the EPN in which they live. The information is provided on the home TV by an application that runs on a small android device (MK908) that is connected to the TV. This device is connected to electricity measurement equipment that measures the electricity consumption of appliances. The measured data is stored in a local small database, analyzed, and displayed to the user. This application is connected to the EMS and receives real-time notifications about suggested changes in electricity and heat consumption based on availability. The notifications are displayed on the home TV. The HEA also records all the activity made by the residents throughout the pilot time. This information will be used to evaluate how effective the pilot is.

The EAA runs on a hand held device and provides a sophisticated interface that tries to attract the residents and should make them aware of the current and historical energy consumption for each appliance at home. For this purpose the research that has been done moves beyond the state of the art in energy feedback technologies by using real-time augmented reality technology on hand-held see-through video to give alerts, interact with the users and allows them to visualize the real-time energy usage of various energy consumption appliances in the home. To do that without tagging the appliances, a special real-time computer vision environment has been created. It runs novel methods for objects recognition specially designed for identifying several target appliances within people's homes.

This method also enables the augmentation of 2D and 3D graphical objects on the hand held display by overlaying text and figures over the images of the appliances. This provides a natural and clear view of real time information without the need to go through menus or access websites. The information includes notifications on the current status of current energy availability that are provided by the EMS. The augmented reality interface can also provide suggestions for actions that can be carried out by the resident for each appliance. The effectiveness of this novel approach will be tested during the end user pilots later on.

Figure 4 below shows the features of the augmented reality interface in action. Firstly the microwave, which has been captured by the camera of the mobile phone carried by the user, has been correctly identified from the picture. Secondly the background IDEAS software has detected a message from the EPN that the renewable energy supply will be low from 10am to 2pm. This is shown to the user in the top white text area.

Finally the software has combined this information with the fact that microwaves have high peak energy consumption and has produced the request in yellow text that the user might wish to not use their microwave during the period of low availability of renewable energy. Since such messages will be associated also with other home appliances, it is hoped that people's usage of energy will be shaped to coincide with periods of high availability of renewable energy, thus making it much easier for the EPN to operate in an energy positive manner.

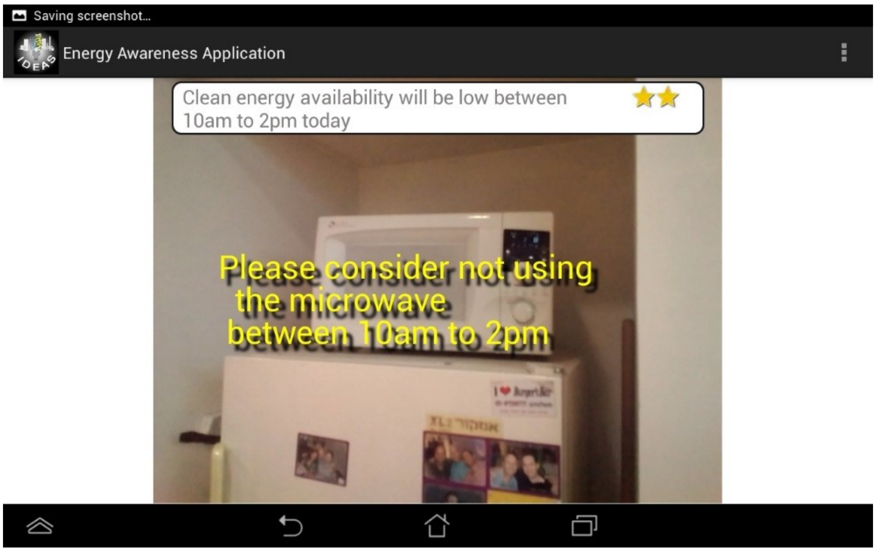

Fig. 4: Energy Awareness Application

Large screens Interface

The objectives of large screens interface applications are to educate residents and/or occupants about energy efficiency of their surrounding environment and to provide and inform them about the impact they have on their own neighborhood. These display the big picture of the neighborhood and can be zoomed in at the neighborhood detail level. These interfaces will display the energy consumption of the whole site as well as the energy consumption of individual buildings. They will show nearly real-time consumption as well as historical data. In order to attract residents/occupants, some alerts, tips and a quiz are also proposed to warn the users of non-sustainable behavior.

The design goals of these interfaces are the following:

- Friendly and intuitive graphic interface
- Encouraging the use of the application
- Application can proceed independently a predefined scenario

As it's not possible to use a tactile screen at the French pilot site, the interfaces there will be implemented as a slide show, mainly focusing on the dynamic data and attractive content. Through a QR code / link displayed on the large screens, the building occupants (students, visitors, etc.) can easily access the full content of the interfaces through any web browser and at any time.

In order to display local information, the application interacts with the EMS. The architecture schema showing these interactions is given in Figure 5.

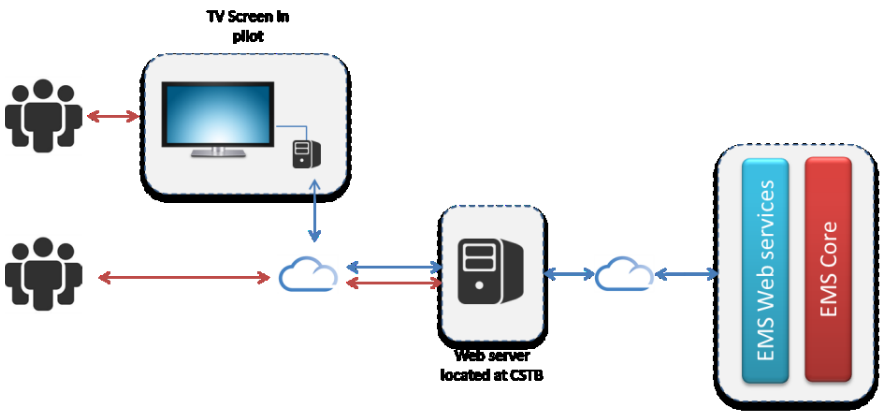

Fig. 5: Interaction of user interfaces with EMS, a Web server and users

A web server hosting the large screens interface application is located offsite at the premises of Centre Scientifique et Technique du Bâtiment (CSTB) in France. It is developed using Ruby and communicates with the EMS through web services to retrieve local data from the pilots. The large screens are installed at strategic locations at the Finnish and French pilot sites. A mini Android computer is connected to each large screen at the pilot sites: it runs the application through a simple web browser and displays it on the screen. Users can also access the application at anytime and anywhere through their personal devices (e.g. tablets, PC, etc.), using a simple web browser. Depending on the pilot site, the content of the large screens interface is available in Swedish, Finnish, English and French. Some screenshots of the large screen interfaces are given in the following figures.

Fig. 6: Finnish context - Large screens application

Fig. 7: Electrical consumption - Large screens application

EPNSP Interfaces

The EPNSP user interfaces (1.10 and 2.1 in Figures 2 & 3 above) are hosted by the IBM® WebSphere Portal embedded by the Intelligent Operations Center ® (IBM® IOC) as part of the EMS. This platform enables modular and flexible application development for these interfaces. They are composed of several screens of text information, many different types of graphs and views used to display data generated by simulation and prediction models and actual data stored inside the EMS data repository.

The main view of the EPNSP interface is a manager dashboard (Figure 8) which summarize most relevant data in real time, for example the current (simulated) energy production in the site, the site energy consumption, the current weather, etc.

The user interfaces retrieve data from the EMS repository using the REST API and they are also connected to the IOC KPI engine (internal feature to the IOC framework) used to calculate different KPIs regarding the performance of the site (see Grilli et al 2014 for more details). The use of the REST API enables lightweight technologies to be used in the client side which give to the EMS interfaces more flexibility and a better user experience. The user interfaces make an extensive use of the Dojo framework (Dojo), an industrial level JavaScript framework partly developed by IBM. The EPNSP User interfaces adopt the same generic structure for each of the pilot sites:

- A login screen
- A site view (3D for Bordeaux, GIS for Porvoo) from which you get detailed views (per building)
- A site level dashboard
- Multiple charts / graphs showing detailed data (historical data, predictions).

Some of the EPNSP user interfaces screenshots are given in Figure 8 and Figure 9:

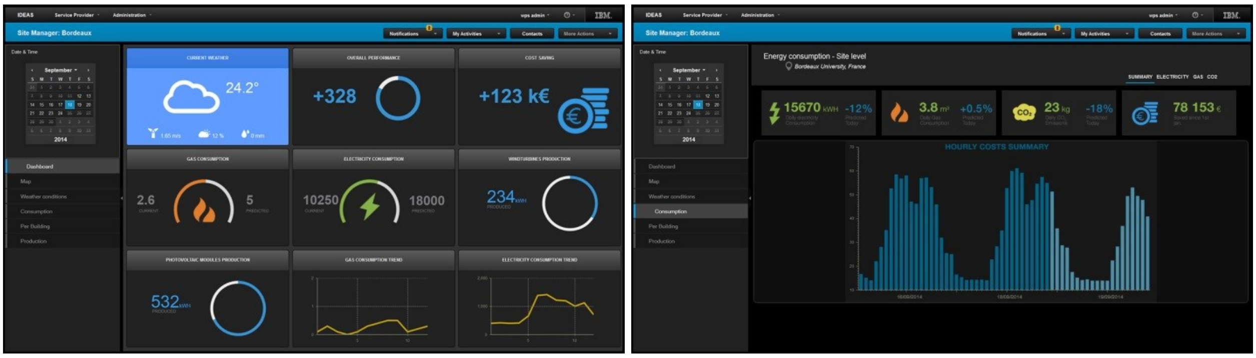

Fig. 8: Dashboard (left) and Energy Consumption of Bordeaux site (right) for Bordeaux Site Manager

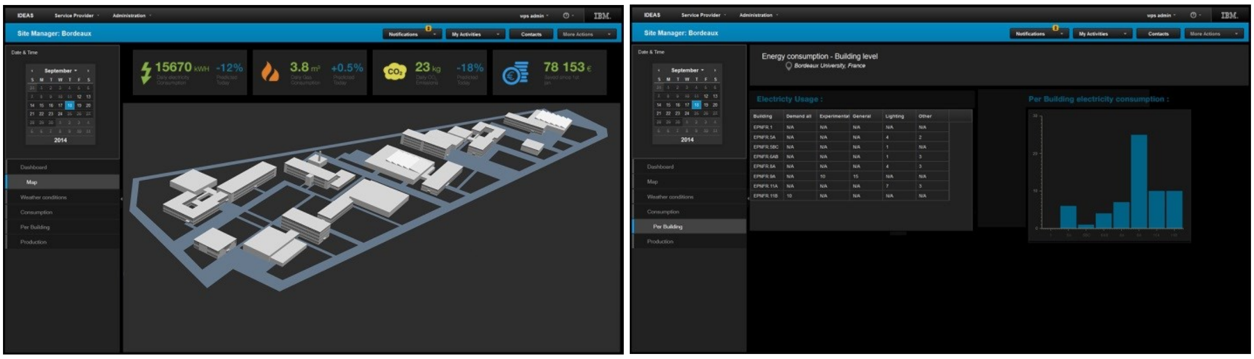

Fig. 9: Bordeaux Site Map (left) and Energy Consumption per building of Bordeaux site (right) for Bordeaux Site Manager

IUT Bordeaux 3D virtual space

The IDEAS project shared 3D virtual space is used to demonstrate the Energy-Positive Neighborhoods (EPN) concepts to remote visitors. The idea is to provide remote visitors with a virtual venue to learn about the IDEAS project, an immersive rich collaborative environment without the need to actually visit the project pilot site. A unique aspect of the virtual environment is the incorporation of simulated energy production and storage elements into the neighborhood representation that do not exist in the real sites, and to show how these are integrated into the intelligent energy management that is developed as part of the IDEAS project.

The environment attempts to be “realistic” in order to involve the students as much as possible. The shared 3D virtual space replicates a portion of the IUT pilot site in Bordeaux, France. It will enable local IUT employees to host external visitors in (virtual) person and to demonstrate the IDEAS project using the visual and data contexts from the physical IUT site.

The virtual site enables visualization of the site global energy consumptions that is available through the actual measurements equipment installed on the site. It focuses on the Civil Engineering department (Figure 10) which is engaged through its activities in energy management and which is equipped with multiple energy systems from which students can learn.

Fig. 10: Civil Engineering Department building (left) and Interactive mock-up showing the stakes at site level (right)

IUT students can enhance the 3D IUT virtual world with new features and virtual information. This will enable the students to be more involved in the IDEAS project and give them a chance to add extensions as they see fit to meet new requirements and project capabilities.

The tool aims at involving the students and informing them about the stakes related to energy consumption at site level. It also presents some simulated production systems embedded in site, illustrates the positive neighborhood functioning based on a balance-sheet including the real consumptions measured on site and the energy production simulated through virtual systems.

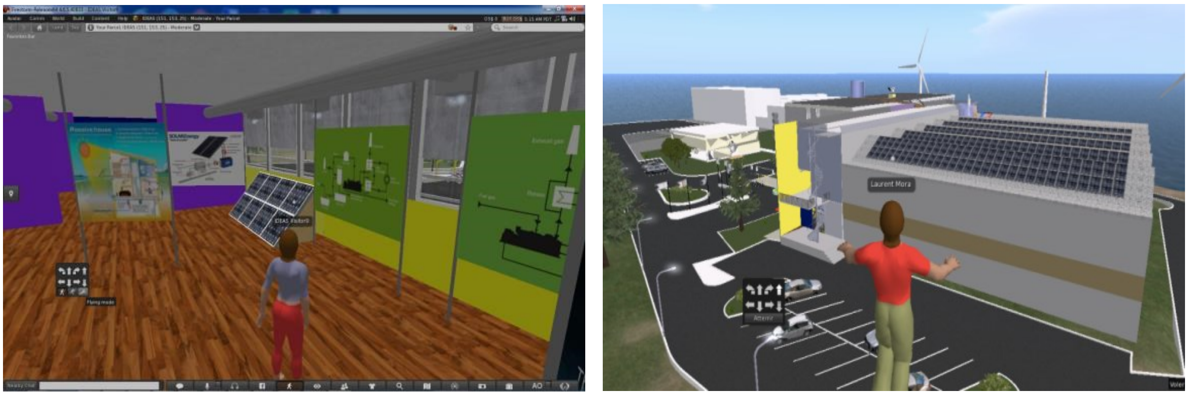

Fig. 11: Room dedicated to the description of energy generation systems (left) and Generation systems simulated for the IUT site - 500m² of PV modules, wind turbines (right)

An interactive mock-up (Figure 10) is present in the Virtual space and explains the stakes at site level. The developed system (will be) connected to the IDEAS energy management system and will show real time energy data of the actual site in the virtual site.

The 3D virtual space includes models of the equipment that is actually installed in IUT for the IDEAS project. In addition, it may include additional equipment that was not actually installed due to budget restrictions for example, energy production (PV panels, wind turbines) and energy storage. Their characteristics and simulation data will be provided by the IDEAS Energy Management System.

Figure 11 (left) is a snapshot of a specific room in the virtual world which is devoted to the description of energy generation systems. This part of the tool could also be used profitably for pedagogical purposes by the teachers enabling a wide dissemination of the energy positive neighborhood process of the site. The generation systems are shown (Figure 11 (right)) with their real time simulated production according to the outdoor conditions.

Another dedicated room shows the management and the different usages of the site with real time data shown on virtual screens the same as the ones which are really installed on site. Illustrations of electrical storage are also shown through a display of electrical vehicles in the site (Figure 12).

Fig. 12: Management and different usages of energy on site (left) and Illustration of electrical storage through electrical vehicles (right)

Finally the visit ends with a virtual round table (Figure 13) where host(s) can discuss any matters arising with the person(s) they have invited into the virtual space.

Fig. 13: Round table concludes the visit

CONCLUSIONS

The incremental rollout and operation of energy positive neighborhoods requires ICT tools for energy awareness and management. User interfaces can play a key role in creating energy awareness in residents and helping EPNSP managers with energy management. In this paper, several user interfaces have been described. These user interfaces have been developed in the context of a collaborative European project involving partners from academia and industry. The effective of these user interfaces will be tested in the demonstration phase at two pilot sites. Future works will include results from the tests of these user interfaces at the two pilot sites and their advantages and limitations.

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